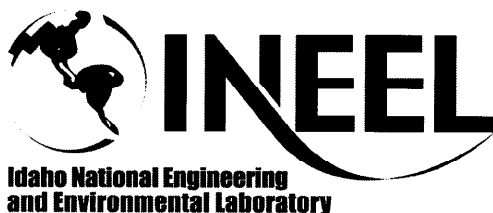


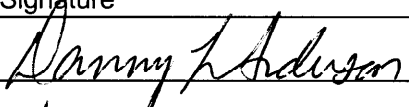
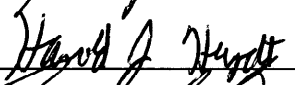
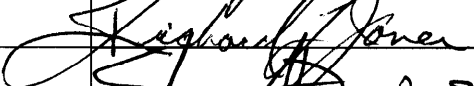
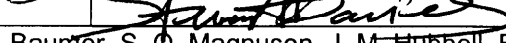
Engineering Design File

Operable Unit 7-13/14 Integrated Probing Project Soil Moisture Instrumented Probe

Prepared for:
U.S. Department of Energy
Idaho Operations Office
Idaho Falls, Idaho



Form 412.14
07/24/2001
Rev. 03

1. Title: Operable Unit 7-13/14 Integrated Probing Project Soil Moisture Instrumented Probe				
2. Project File No.: PF110.12				
3. Site Area and Building No.:			4. SSC Identification/Equipment Tag No.:	
5. Summary: The soil moisture probes are Type B probes to be used in Phase II of the Operable Unit 7-13/14 integrated probing project. They measure the resistivity, soil moisture volume content, and the temperature of the surrounding soil, and track changes through data logging equipment. A commercial, off-the-shelf instrument has been identified and selected. The Engineering Design File describes the soil moisture probe.				
6. Review (R) and Approval (A) and Acceptance (Ac) Signatures: (See instructions for definitions of terms and significance of signatures.)				
	R/A	Typed Name/Organization	Signature	Date
Performer	R	Danny L. Anderson		8/22/2001
Independent Reviewer	R	Harold J. Heydt		8/22/01
Requester	A	Richard L. Jones		8/22/2001
Approver	A	Steven A. Davies		8/22/01
7. Distribution: (Name and Mail Stop)		D. L. Anderson (5), A. R. Baumer, S. O. Magnuson, J. M. Hubbell, ER Document Control (3), G. A. Beitel, D. M. Everett, R. W. Horne, K. A. Wooley, R. L. Jones, T. E. Sluder, B. E. Johnson, S. A. Davies, R. D. Sayer		
8. Records Management Uniform File Code (UFC): 6400				
Disposition Authority: ENV1-k-2-b			Retention Period: Cutoff at project completion. Destroy 25 years after project completion.	
EDF pertains to NRC licensed facility or INEEL SNF program?: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No				
9. Registered Professional Engineer's Stamp (if required) N/A				

1. Project File No.: PF110.12 2. Project/Task: Operable Unit 7-13/14 Integrated Probing Project
3. Subtask: Probing, Logging, and Instrumentation Project

4. Title: <u>Operable Unit 7-13/14 Integrated Probing Project Soil Moisture Instrumented Probe</u>				
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6. Distribution (complete package): D. L. Anderson (5), A. R. Baumer, S. O. Magnuson, J. M. Hubbell, ER Document Control (3), G. A. Beitel, D. M. Everett, R. W. Horne, K. A. Wooley, R. L. Jones, T. E. Sluder, B. E. Johnson, S. A. Davies, R. D. Sayer Distribution (summary package only):				
7. Review (R) and Approval (A) Signatures:(Minimum reviews and approvals are listed. Additional reviews/approvals may be added.)				
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Independent reviewer	R	Harold J. Heydt		
Requestor	A	Richard L. Jones		
Approver	A	Steven A. Davies		

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ACRONYMS

ARA	Applied Research Associates
AWG	American wire gauge
CPT	Cone Penetrometer Test
EDF	engineering design file
INEEL	Idaho National Engineering and Environmental Laboratory
OD	outside diameter
OU	operable unit
SMP	soil moisture probe
SMR	soil moisture resistivity
T&FR	technical and functional requirements
VAC	variance at completion
VDC	vendor data control

Operable Unit 7-13/14 Integrated Probing Project Soil Moisture Instrumented Probe

1. INTRODUCTION

This engineering design file (EDF) describes the design of the soil moisture probes to be used in the Operable Unit (OU) 7-13/14 integrated probing project. This EDF is brief because the subject probe is an existing, commercial, off-the-shelf product, and there is essentially no Idaho National Engineering and Environmental Laboratory (INEEL) design or fabrication involved.

2. BACKGROUND

The OU 7-13/14 integrated probing project consists of two probing phases, to be performed in the Subsurface Disposal Area at the Radioactive Waste Management Complex, to support the OU 7-13/14 comprehensive remedial investigation/feasibility study. The first phase of probing will use probes of the type successfully installed in Pit 9 for the OU 7-10 staged interim action. These Type A probes will be logged and used to site the instrumented (Type B) probes to be installed as the second phase of probing. The Type A probe is a capped pipe driven through the waste that allows nuclear logging instruments to be lowered into the waste for characterization. The Type B probes use a direct-push technology, with sonic assistance, as needed, to install tensiometers, suction lysimeters, soil moisture sensors, and vapor ports into and beneath the waste. This will allow long-term monitoring of the moisture within the pits and release of contaminants from the waste.

The soil moisture probes described in this EDF are Type B probes that will be used to measure the amount of moisture in soil surrounding the probe and track changes in the amount of moisture.

3. REQUIREMENTS

Requirements for the soil moisture probes are derived from *Technical and Functional Requirements for the Operable Unit 7-13/14 Integrated Probing Project Type B Probes* (T&FR) (INEEL 2001). Derived requirements are described below and traced to the applicable requirements in the T&FR.

3.1 Measurements and Data Collection

The soil moisture probe will measure the amount of moisture, temperature, and electrical resistivity in the soil at depths down to 25 ft (7.6 m).

Basis: T&FR Sections 3.1.2.1.1 and 3.1.2.2.2.

3.2 Material Chemical Compatibility

Probe casings and instruments will be fabricated using materials that are chemically compatible with the pit and soil vault row environments. The *OU 7-10 Materials Compatibility Study for Stage I and Stage II Enclosures* (O'Holleran 2000) will be used as a guide.

Basis: T&FR Section 3.3.2.1.

3.3 Design Life

The design life of the system will be a minimum of 10 years; consumable, replaceable parts may have shorter design lives.

Basis: T&FR Sections 3.2.5.1, 3.2.5.1.1, and 3.2.5.1.2.

Explanation: Even after the useful operating life has expired (see Section 3.4), the probe casings, instruments, and seals will have to maintain structural integrity to prevent releases of contaminated liquid or gas at the surface throughout a 10-year period from the date of installation.

3.4 Useful Operating Life

The useful life of the system will be at least 3 years, though not continuous or uninterrupted.

Basis: T&FR Sections 3.2.5.1 and 3.2.5.1.2.

Explanation: The instrument must be capable of collecting data throughout a 3-year period from the date of installation.

3.5 Seals and Barriers

The soil moisture instruments will provide no pathway to the surface for contaminant gases or liquids, and probe casings will have at least one seal at each joint to minimize the likelihood of such contaminants entering and exiting to vent or spill at the surface. (The fact that contaminants must enter and exit through a seal means a double barrier has been provided.)

Basis: T&FR Section 3.1.2.1.2.

3.6 Physical Compatibility with Existing Drill Rig

The soil moisture probe will be capable of being installed using the Modified Hawker Siddley Super Drill 150, Series 2, ResonantSonic Drill, currently owned by Waste Area Group-7, in both direct-push and sonic-vibration modes.

Basis: T&FR Section 3.1.2.1.7.

3.7 Data Logging

The instrument electronics will have a connection for and be capable of (1) providing data-to-data logging equipment, (2) displaying and temporarily storing measured data, and (3) transferring the data to a personal computer in real time or upon demand.

Basis: T&FR Section 3.1.2.2.5.

3.8 Targeted Depths of Measurements

It has been determined that soil moisture volume content should be measured at nominal depths of 6, 14, and 22 ft (1.8, 4.3, and 7 m) at each probe location. To meet this requirement, the soil moisture instruments will be stacked, three instruments per location, with selectable spacing between each instrument, in 1-ft (30-cm) increments.

Basis: Derived requirement based on engineering judgment and knowledge of structure of soil and waste layers.

4. DESCRIPTION

Sources for an existing, suitable, off-the-shelf instrument were researched and one source was identified. Bids were requested from several potential providers; however, only the originally identified source responded as being able to fully meet the requirements, and their instrument was selected. The vendor of the soil moisture probe is Applied Research Associates (ARA). The manufacturing arm of their company is VERTEK.

The entire probe string (i.e., instrument, push rods, cables, and connectors) will be fabricated by VERTEK and procured from ARA. The only fabrication performed by INEEL will be to machine a female thread into a thread adapter coupling blank that will be provided by ARA.

4.1 Applied Research Associates and VERTEK Components

The following sections describe the components to be fabricated by VERTEK and procured from ARA.

4.1.1 Soil Moisture Instrument

The VERTEK soil moisture and resistivity (SMR) probe was selected to measure resistivity, soil moisture volume, and temperature. The SMR probe, shown in Figure 1, is an existing, commercial, off-the-shelf unit. A schematic for the SMR probe is shown in Figure 2. A manufacturer product description sheet is provided in Appendix A (Vendor Data Sheets).

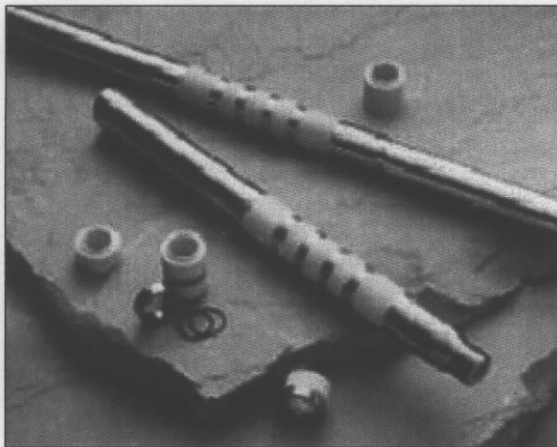


Figure 1. Soil moisture probe.

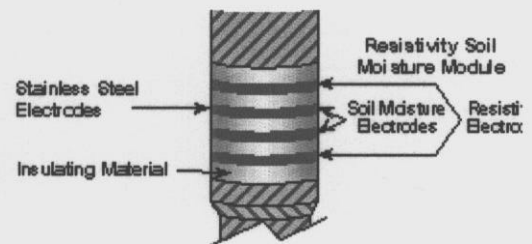


Figure 2. Soil moisture probe schematic.

The body of the instrument is made of 4340 carbon steel that has been heat-treated. A series of electrode rings, made of 304 stainless steel, is located toward the lower end of the instrument. These electrodes are separated by insulating rings made of Ultem 2300, a PolyEtherImide. A vendor product specification sheet for this material is provided in Appendix B (Vendor Product Specification Sheet). The outer set of rings measures resistivity, and the inner set of rings measures capacitance, to calculate soil moisture. There is a Viton O-ring between the rings to provide a primary seal against contaminated soil, gas, or waste entering the instrument body.

The points where the electrical signal cables enter and exit the instrument body at each end are sealed with an epoxy. The printed circuit board inside the instrument, and associated connectors, are encased in a potting material to dampen vibrations anticipated if the sonic drilling mode is engaged and to prevent damage or loosening of connections. The material is a two-component polyether-based urethane casting system, designated as “60A Liquid Urethane,” made by Forsch Polymer Corporation (a Material Safety Data Sheet is available). This potting material also serves as a second internal seal or barrier. Thus, each instrument is a sealed, self-contained unit, providing no pathway for contaminants.

Three instruments will be stacked at each location, separated by push-rod spacers to adjust the placement depth. The three instruments are connected in serial and are software-indexed so that all three can be monitored through the same four-wire signal cable. A cabling diagram is included in Appendix C (Soil Moisture Probe Cabling Diagram).

The only way contaminants can reach the surface is if they enter at a joint above the top-most instrument, thus breaching one seal, and exit at another joint or through the water seal kit above surface, thus breaching a second seal.

The soil moisture instruments come in two sizes (diameters): 1.75 and 2 in. (4.5 and 5 cm). The 2-in. (5-cm) diameter instrument was selected to reduce the likelihood of buckling. Supporting analysis is included as Appendix D (Diameter Analysis).

4.1.2 Probe Tip

The probe requires a tip to provide a durable bit for leading the probe downward as the probe is pushed into the ground. The VERTEK standard dummy tip will be used. It is a pointed cone with no teeth or auguring edge, as shown in Figure 3. The tip is made of 4340 carbon steel that has not been heat-treated. Initially, there was a recommendation to blunt the point of the standard tip to reduce heat generation. However, an analysis was performed and documented in *Operable Unit 7-13/14 Integrated Probing Project Thermal Analyses of Type B Probes Driven with the ResonantSonic Drill* (Beitel and McCreery 2001) that demonstrates that the standard tip is acceptable. The standard tip will be used as is.



Figure 3. Probe tip.

4.1.3 Push Rods

Segments of rigid pipes referred to by ARA and VERTEK as push rods, and by INEEL as probe casings, will be used to drive the instrumented probes into the ground and to provide conduit for the signal cable to the surface.

Consideration was given to using INEEL 2.5-in. (6.35-cm) diameter probe casings that are already being used for three other probes. However, because the instruments themselves are significantly narrower and the threads are proprietary, this idea was abandoned because of the requirement to stack the

soil moisture probes. Too many thread adapters would have been required and the diameter up and down the string would have changed too frequently to ensure any structural integrity and stability. Consideration was also given to fabricating narrower versions of the INEEL probe casings; however, the need for thread adapters remained because of the proprietary thread. Therefore, this also was deemed an unreliable and undesirable design.

It was decided that VERTEK-proven push rods would be procured and used. These push rods, with an outer diameter of 2 in. (5 cm), are made of 4130 carbon steel. Tests were conducted in the Cold Test Pit to determine whether the thread joints needed to be heat-treated for hardening. It was shown that heat-treating was not needed. This reduced both cost and delivery schedule.

The rods will be procured in three lengths to allow the ability to customize the overall length of the probe string and the depth it can reach, and the depth placement of each of the stacked instruments. The sizes procured will be 3.3 ft (1 m) (standard), 2, and 1 ft (61, and 30 cm). The push-rod segments will have the same outer diameter as the soil moisture instruments. Each joint has one O-ring.

4.1.4 Thread Adapter Coupling Blank

The interface between the VERTEK push rods and the existing drill rig is a push shoe that is being designed (under separate EDF). This push shoe will use a large, modified ACME box-thread design. Because the thread on the VERTEK push rods is proprietary, a push shoe adapter is required to connect the rods to the threaded push shoe on the existing drill rig. VERTEK will provide a thread adapter coupling blank, shown in Figure 4. The forward end will have the male end of their thread, and the rear end will be unfinished, ready for INEEL to machine. The blank will be made of 4340 carbon steel that has not been heat-treated. Because the drill rig push shoe will be designed to accept INEEL 2.5-in. (6.4-cm) probe casings, using an INEEL box-thread design, the finished thread adapter coupling will have a final diameter of 2.5-in. (6.4 cm) for connecting to the push shoe.

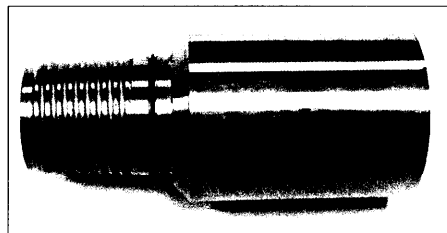


Figure 4. Thread adapter coupling blank.

4.1.5 Signal Cable to Data Logger

Each soil moisture instrument connects to the next by an integrated four-wire cable. A diagram showing all cables and connectors is included in Appendix C. The topmost instrument, however, requires an extension cable to reach the surface. These cables provide the signal from the electronics in the instruments for logging data. The extension cables are 25 ft (7.62 m) long. This is more than sufficient length. Excess will be coiled or the cables can be cut and shortened in the field and the connector reattached. The connector at the surface is a Turck *eurofast* BS8141-0, shown in Figure 5. Data logging is performed through a separate subsystem described in, "OU 7-13/14 Integrated Probing Project Data Acquisition System for Type B Probes Design (Draft)" (Johnson and Larsen 2001), which provides the mating connector for this interface.

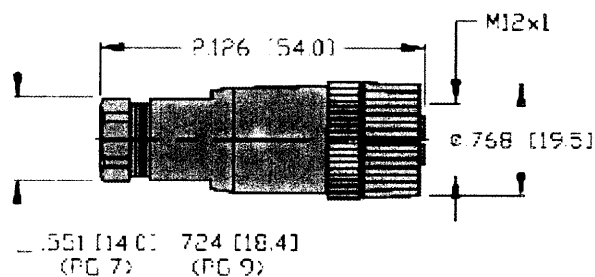


Figure 5. Single cable connector.

4.1.6 Water Seal

A 12-in. (30-cm) piece of push rod will be machined to accept a water seal kit. This extension rod will be threaded to the top of the probe string, aboveground, to provide the final seal to contain any contaminants that may enter into the rods, and to provide weather-proofing to keep moisture from rain and snow out. The water seal kit includes a compressible Viton gasket that is tightened to form a seal around the data signal cable that extends from the top of the rod (see Figure 6).

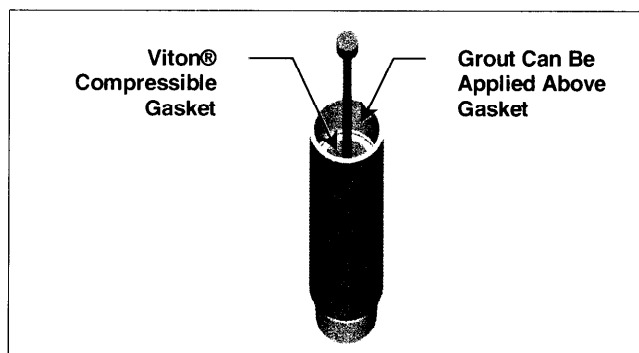


Figure 6. Water seal extension rod.

An initial delivery of a water seal kit was checked out in the Cold Test Pit and proved inadequate. The hole in the gasket was too large, and sufficient compression could not be applied to close it up. The vendor has agreed to make the hole smaller. In addition to the water seal kit, the top of the extension rod can be filled with grouting to enhance the seal if the seal appears inadequate after compression has been applied.

4.1.7 Double Barriers

The instruments are sealed, nonsampling units. As stated in Section 4.1.1, the only way contaminants can reach the surface is if they enter at a joint above the top-most instrument, thus breaching one O-ring seal, and exit at another joint or through the water seal kit above surface, thus breaching a second seal. This effectively places two barriers in the path of subsurface contaminants. Radiation Control has approved this implementation.

4.2 Idaho National Engineering and Environmental Laboratory Components

The following sections describe the components to be fabricated or modified by INEEL.

4.2.1 Thread Adapter Coupling

The rear end of the thread adapter coupling blank, provided by VERTEK, will be machined by INEEL. A female thread, compatible with the INEEL box thread for the probe casing joints, will be machined into the rear end of the blank (see Drawing 515919 in Appendix E [Drawing 515919, Coupling Assembly]). This thread adapter coupling will be attached to the drill rig push shoe so it can accept the VERTEK push rods.

4.3 Calibration

The instruments are precalibrated in the laboratory by the vendor using moisture level extremes (zero moisture and 100% saturation). Once the instruments have been driven into the subsurface, they cannot be recalibrated without pulling them back up, which will not happen in the Subsurface Disposal Area. The ARA has observed no drift during a 6-month period of aboveground storage. Longer periods have not been tested because, in the past, ARA has retrieved its probes for reuse rather than leaving them in-ground. But ARA has stated that as long as the oscillating frequency remains stable, there should be no drift. Changes to the oscillating frequency would only be caused by tampering with internal components (e.g., changing capacitance, lengthening wires), which is impossible once the probes have been driven. Therefore, although recalibration is not possible, it also should not be needed.

The only other source of inaccuracy is temperature differences from the laboratory temperature used for calibration. Worst case, for 100% saturated soil, the coefficient increases to about 0.4% soil moisture per degree Celsius. Since the soil moisture probes also measure soil temperature, the soil moisture data can be corrected after collection (in the spreadsheet), or it can be corrected as the data are collected. Temperature is measured with a diode, which does not drift and does not require recalibration.

4.4 Assembled Probe String and Installation

Figure 7 shows a representation of the major components involved in the soil moisture probe string. Appendix F (Parts List) provides a parts list. A figure, showing three stacked soil moisture probes relative to surface, overburden, waste, underburden, and bedrock, is included as Appendix G (Stacked Probes). The soil moisture probe will be capable of being installed using the Modified Hawker Siddley Super Drill 150, Series 2, ResonantSonic Drill currently owned by Waste Area Group-7, in both direct-push and sonic-vibration modes. The drill rig will perform direct push only, for as long as possible. When direct pushing ceases to advance the probe string, if the desired depth has not been reached and it is felt that refusal has not been reached, then sonic-vibration mode will be engaged to drive the probe further, if possible. The probe string should not be rotated during insertion. The ARA has warned that rotation can strip the electrodes, rendering the instruments unusable.

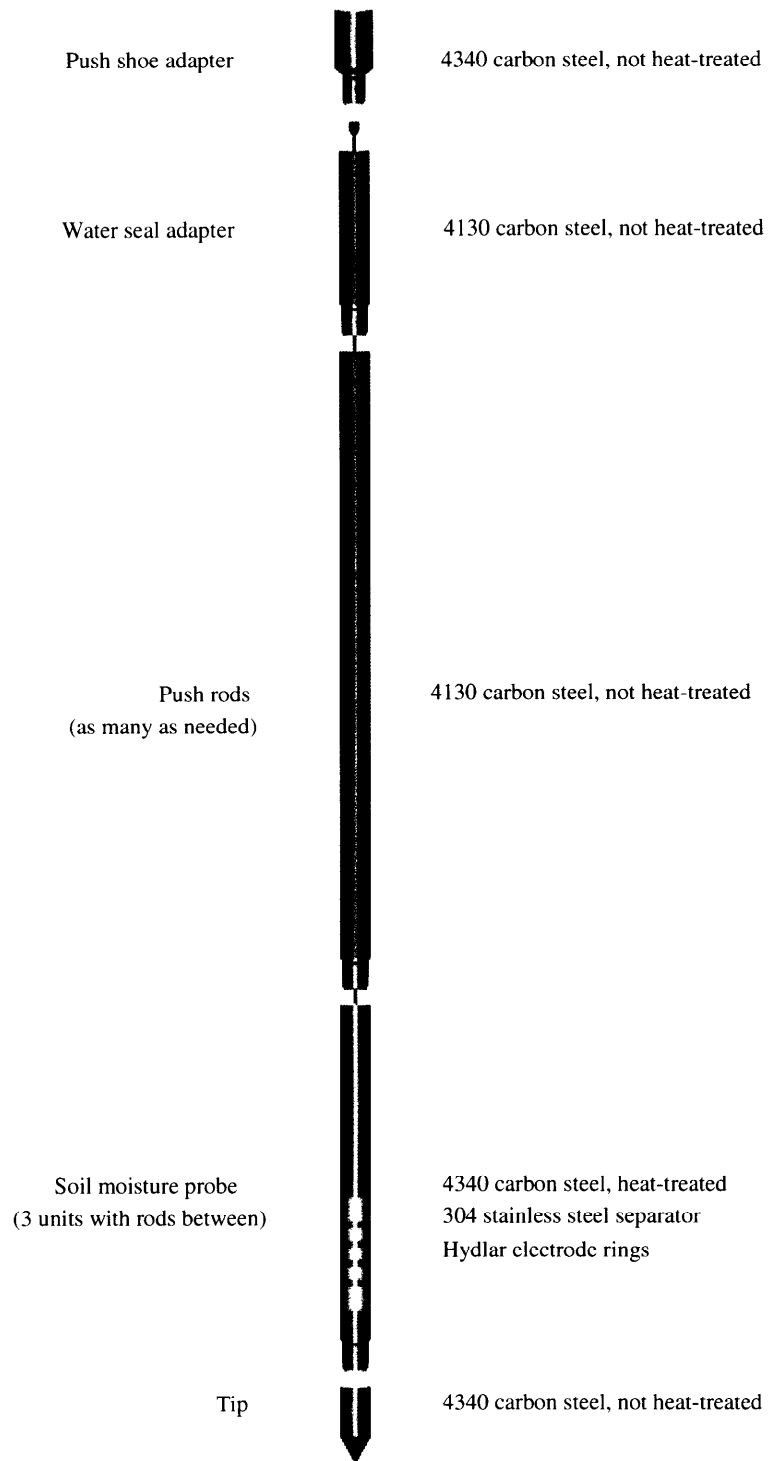


Figure 7. Soil moisture probe string.

5. REFERENCES

- Beitel, George A., and Glen E. McCreery, 2001, *Operable Unit 7-13/14 Integrated Probing Project Thermal Analyses of Type B Probes Driven with the Resonant Sonic Drill*, Engineering Design File EDF-ER-254, Rev. 0, Idaho National Engineering and Environmental Laboratory, Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho.
- INEEL, 2001, *Technical and Functional Requirements for the Operable Unit 7-13/14 Integrated Probing Project Type B Probes*, INEEL/EXT-2000-01429, Technical and Functional Requirements TFR-105, Rev. 0, Idaho National Engineering and Environmental Laboratory, Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho.
- Johnson, Briam E., and Ty Larsen, 2001, "OU 7-13/14 Integrated Probing Project Data Acquisition System for Type B Probes Design (Draft)," Idaho National Engineering and Environmental Laboratory, Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho.
- O'Holleran, Thomas P., 2000, *OU 7-10 Materials Compatibility Study for Stage I and Stage II Enclosures*, INEEL/EXT-2000-00926, Engineering Design File EDF-ER-211, Rev. 0, Idaho National Engineering and Environmental Laboratory, Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho.

